Using Very Small Rovers to Explore the Surface of Primitive Bodies

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Topics

- Lessons learned from mobility on Mars

- Science motivation for mobility on primitive bodies

- MUSES-CN: An example rover for missions to primitive bodies

Lessons Learned from Mars

- "Every new site we visit is like having a new mission!"
  - Refrain often heard from members of MER team
  - Assuming even only modest diversity on surfaces of primitive bodies, the same should apply
- Value to Mars exploration falls into two broad groups:
  - Ground truth for orbital measurements, eg. Spectrometers
  - New classes of measurements that can only be conducted on the surface

# Primitive Body Applications: Ground Truth

- Typical core payload for primary spacecraft includes:
    - Camera
    - IR spectrometer
    - LIDAR
    - Radar
- Rover camera ground truth includes surface context to mm scale
- Rover spectrometer ground truth includes surface mineralogy and spectral diversity for "unmixing" of remote spectra
- Rover telecom system might be used for resolving surface morphology and/or topography ambiguities

Primitive Body Applications: Surface-only measurements - a few examples

- Microscope would return images at the mineral grain size
- Small APXS could return elemental composition not obtainable remotely
- Small Raman spectrometer could yield both mineralogical and organic composition information
- Micro-capillary electrophoresis instrument could identify specific organic molecules and determine their chirality
- Ground-penetrating radar might reveal near surface structure
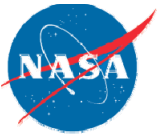
MUSES-CN - A brief history

- NASA approved and funded a "nano-rover" for the MUSES-C (now Hyabusa) mission in 1997
- To be built at JPL
- International science team defined science requirements and key instrument performance parameters
- Substantial progress was made in three years of development
- But, nano-rover project was canceled for budgetary constraints

MUSES-C and -CN Science Objectives

MUSES C and MUSES CN Instruments and Science Objectives								
	MUSES C Orbiter Instruments					MUSES CN Instruments		
	Imager	**NIS**	**LIDAR**	**XRS**	**Sampler**	**Imager**	**NIS**	**AXS**
Personnel Collaboration	NASA Team Member	NASA Team Member	NASA Team Member		NASA Team Member	ISAS Team Member	ISAS Team Member	ISAS Team Member
Science Objectives								
Determine the asteroid's global physical structure including size, shape, volume and density	X		X			X		
Measure the elemental and mineralogical composition of the asteroid's surface with sufficient accuracy to enable comparisons with major meteorite types	X	X		X	X	X	X	X
Characterize the geology and morphology of the asteroid's surface	X	X	X			X	X	
Infer regolith and texture properties of the asteroid's surface	X	X	X			X	X	
Return asteroid surface samples to Earth for detailed elemental composition measurements					X			

NIS: Near Infrared Spectrometer; **XRS**: X-Ray Spectrometer; **AXS**: Alpha X-Ray Spectrometer
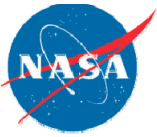
MUSES-CN Nano-Rover Concept

Rover Characteristic	Value
Mass	1300 grams
Size	14 x 14 x 6 cm
Power Capability	2.3 W (normal incidence)
Max. velocity, a) rolling contact b) hopping or skimming	a) 1.5 mm/ sec b) 10 cm/sec
Data rate (quoted at 20km range to OMRE receiver)	4800 bits per second
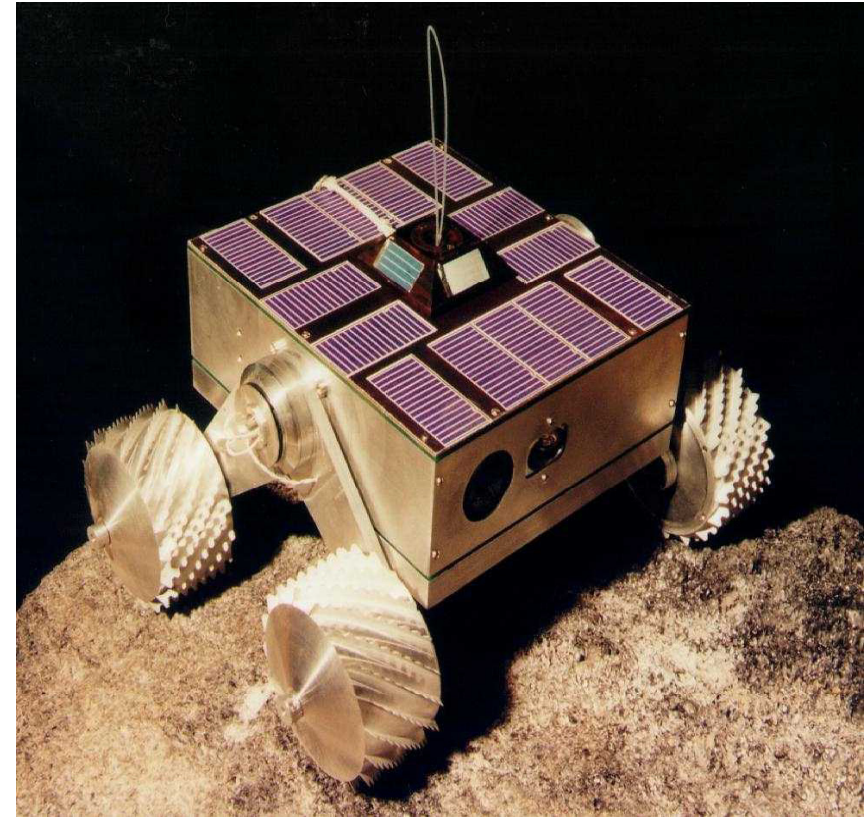
MUSES CN nano-rover. The rover has a mass of about 2.5 pounds (1300 grams) and is about 14x14x6 cm in size.
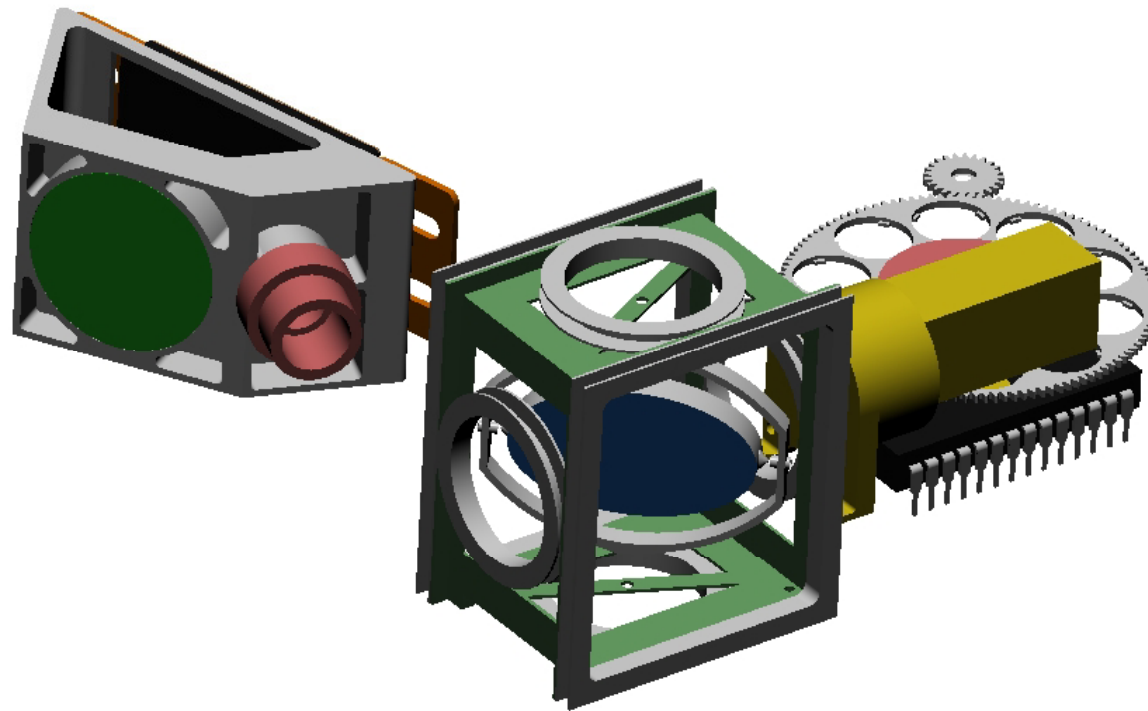
MUSES-CN Nano-Rover Mechanical

Solar Panel substrates

Substrate thermal isolators

Shoulder/Struts

Wheel

Wheel

Motors[10]

Fold Mirror

IR Spectrometer

Phase Change Assembly

Battery

Optical Bench

Gimbaled Mirror

Camera/Filter Wheel

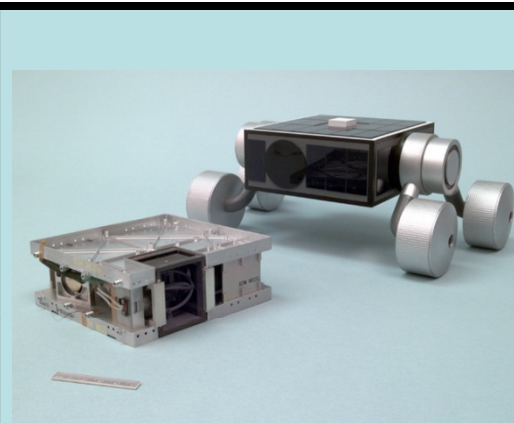Shoulder/Struts

Wheel

Wheel

Side Panel Radiators

Phase Change Assembly
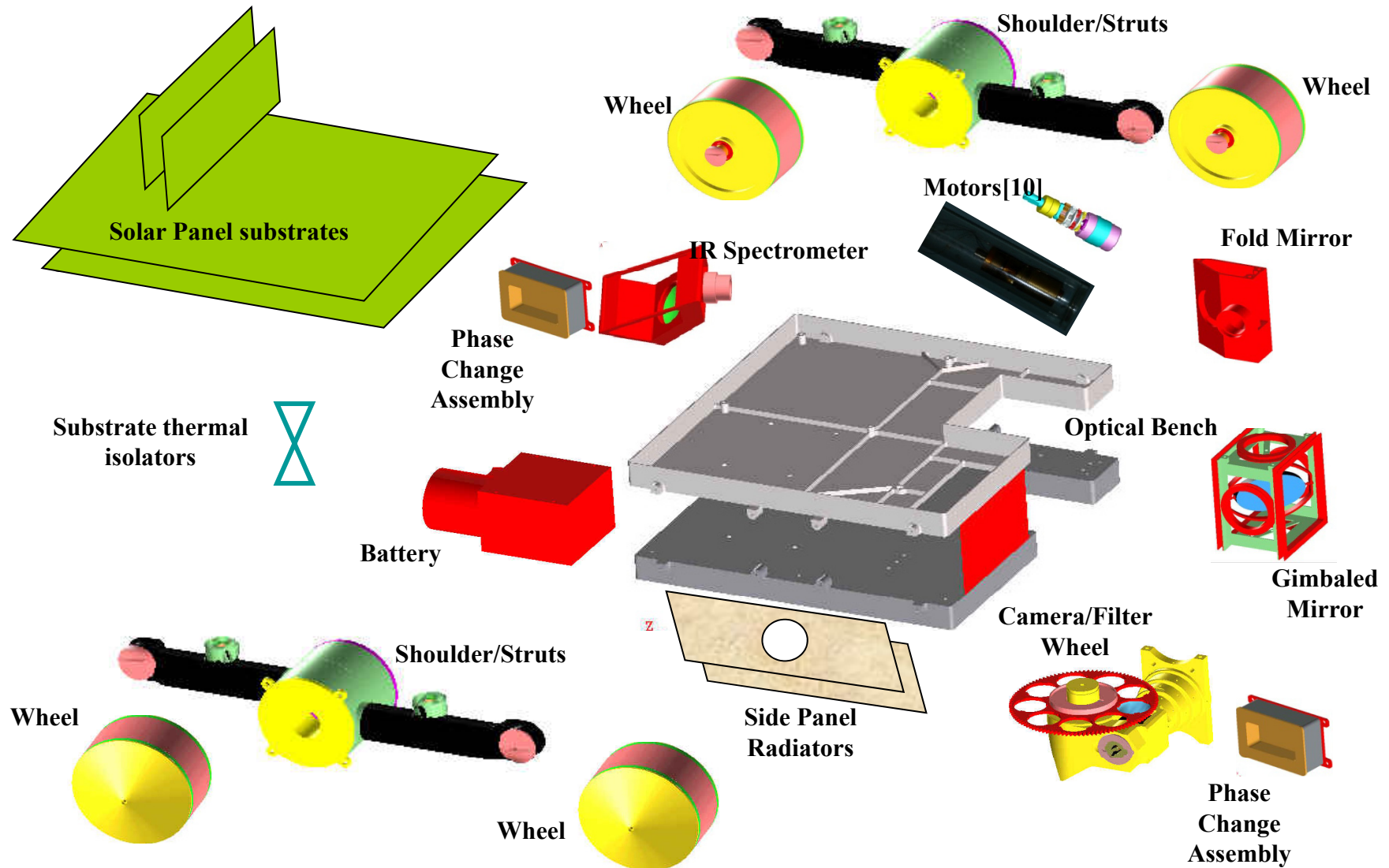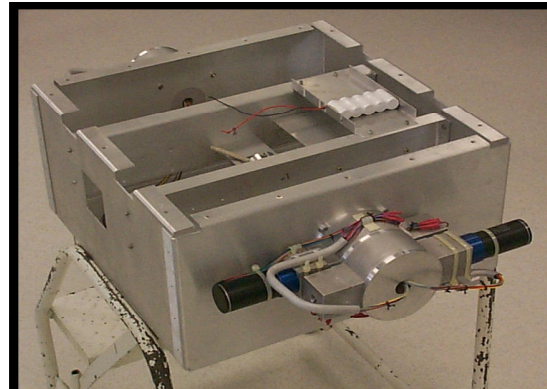
Camera and Spectrometer Performance

- Key characteristics to be excerpted from Ross, 2000 paper that was cleared for presentation at international meeting
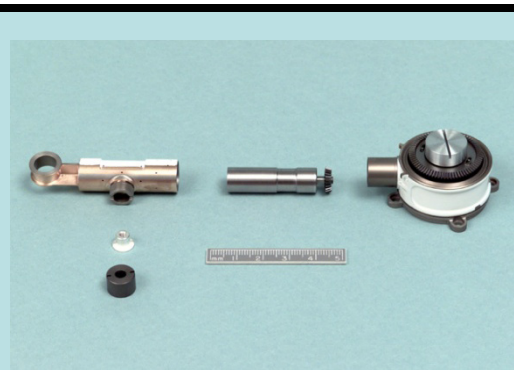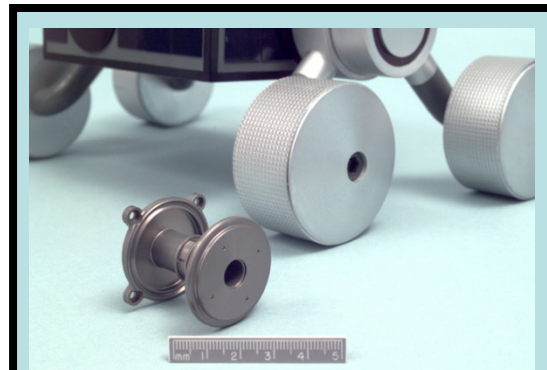
MUSES-CN Hardware Development Status

EM Optical Bench

MUSES CN SW Development Model

Flight Strut & Wheel

Flight Wheel Hub

The Future

- Work completed on the MUSES-CN nano-rover provides an existence proof that such a capability could be developed for spaceflight

- MUSES-CN was based on Mars Pathfinder Sojourner experience but we now have extensive MER and MSL experience and knowledge

- All MUSES-CN drawings, hardward and software developed prior to cancelation exist and could be used

- Next steps would be:
  1. Define science objectives
  2. Define overall payload mass and volume constraints on a rover system including deployment device
  3. Revisit existing designs, H/W and S/W in light of MER and MSL knowledge
  4. Revisit science payload